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Design of a Steel Grand-Stand

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# DESIGN OF A STEEL GRAND-STAND

BY

LEONARD MAUEL

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## THESIS

FOR THE

DEGREE OF

BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

IN THE

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

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May 25, 1911

I recommend that the thesis prepared under my supervision by LEONARD MAUEL entitled Design of a Steel Grand-Stand be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

*C. W. Malcolm*

Asst. Professor of Structural Engineering.

Recommendation approved:

*Ira O. Baker*

Head of the Department of Civil Engineering.





## DESIGN OF A STEEL GRAND-STAND.

A large majority of the grand-stands now in existence are built almost entirely of wood. Within the last few years, however, many of the most important structures throughout the country have been rebuilt using steel or reinforced concrete. The reasons for this improvement are three fold: (1) a fire-proof structure is desired, (2) a more reliable material is needed for stands having a greatly increased seating capacity, and (3) the use of a more durable material is ultimately cheaper.

Whether an all-steel or a reinforced concrete grand-stand should be built can be decided only when the conditions existing at a particular location are known. In most cases, however, the all-steel structure will be the better, because (1) it is easier to properly erect, (2) its first cost is usually less, and (3) it is easier to inspect during and after construction, and thus the condition of the structure can be determined at any time. The largest all-steel grand-stands now in existence are, the one at Belmont Park, L. I., having a seating capacity of 11,000, and the one at the Pittsburgh National League Ball Park, having a capacity of about 30,000.

The grand-stand herein designed is for one side of the Illinois Football Field, and to afford a good view for the spectators in the upper deck it must be so placed that the distance from the front of the stand to the gridiron is about seventy-five feet.



This allows the building of a running track around the field, which is visible only to those in the lower deck. It is probable that this would not cause any inconvenience, because a track-meet seldom attracts as large a crowd as a football game. The main floor of the stand is  $333 \frac{1}{3}$  feet long, 62 feet deep, and rises to a height of 20 feet. It is supported by columns spaced  $16 \frac{2}{3}$  feet apart, longitudinally, and 14 feet 7 inches, transversely. The upper deck forms the front half of the roof, which extends the full length of the main floor, and is 70 feet wide. It is supported by transverse trusses, spaced  $16 \frac{2}{3}$  feet apart, which are in turn supported by longitudinal trusses, each  $66 \frac{2}{3}$  feet long. This arrangement reduces to a minimum the number of columns obstructing the lower deck. The slope of the seats in the upper deck is two in three, thus making the highest part of the stand about 53 feet above the base of the columns. A space  $18 \frac{1}{2}$  inches by 31 inches is allowed for each person. The aisles, which are  $33 \frac{1}{3}$  feet apart, are 52 inches wide for the first 12 tiers of seats in the lower deck, and 34 inches for the remaining 12 tiers and the upper deck. This makes the capacity of the main floor 4680 and that of the upper deck 2600, a total of 7280.

In the design of the structure dead load, live load and wind load were considered, it being unnecessary to design for snow load, as the combination of live load and snow load would never occur, and therefore the larger one governs. The dead load was computed and was found to be about 40 pounds per square foot of horizontal projection on that part subject to live load, and





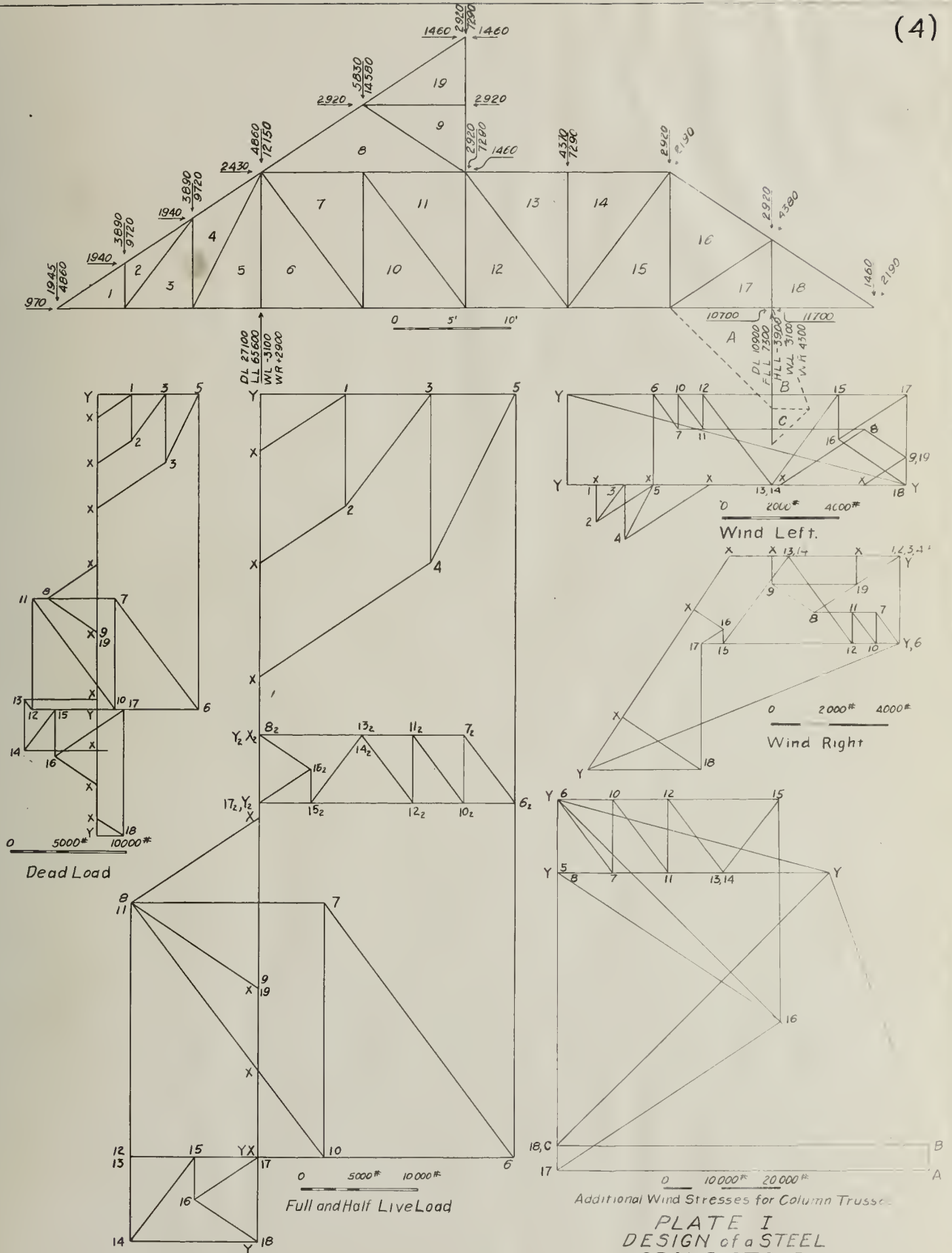
20 pounds at other places. The live load was taken at 100 pounds per square foot. This allows a coefficient of impact of 100 per cent when the stand is filled to its capacity. The wind load was computed from Duchemin's formula for a pressure of 30 pounds per square foot of vertical projection. It was assumed that the entire horizontal component of the wind was taken by the rear columns and was transferred by them to the seat-beam. A heavy anchorage is, therefore, necessary for the lower end of the seat-beam.

The entire structure, with the exception of the column footings and the wearing surface of the floors, is to be of steel. The seats will be a type of opera chair. On account of the difficulty of making a good connection of the front columns with the trusses, channel-sections were discarded in favor of Z-bars. It was decided to use slag concrete in the roof and floors because of its small weight, but ordinary limestone concrete will be used in the footings. Four tons per square foot was assumed as the bearing power of the soil.

The stresses in the transverse trusses were obtained by graphic methods, while all others were computed algebraically. The stress diagrams for the transverse trusses are shown in Plate I, and the tables of stresses are shown on *Tables I and II*. Plate II contains outline drawings of all trusses and main members, and shows the maximum and minimum stresses, together with the sections designed. Plate III contains a detailed drawing of the transverse truss over the columns and a front longitudinal truss, together with the floor detail for both the upper and lower decks, and the







# PLATE I DESIGN of a STEEL GRAND-STAND

Stress Diagrams for  
Transverse Trusses

L. Mauer

Thesis Work



TABLE I

(5)

## STRESSES IN INTERMEDIATE TRANSVERSE TRUSSES.

	Dead Load	Full Live Load	Half Live Load	Wind Left	Wind Right	Max.	Min.
x- 1	+ 2500	+ 8700	+ 8700	0	0	+12200	+3500
x- 2	+ 3500	+ 8700	+ 8700	- 2400	0	+12200	+1100
x- 4	+ 7000	+17500	+17500	- 3500	0	+24500	+3500
x- 8	- 5200	-13200	000	+ 3500	- 3500	-21900	-1700
x-19	+ 000	000	000	+1800	- 1800	+ 1800	-1800
x-19	- 2900	- 7300	000	- 1000	+1000	-11200	-1900
x- 9	- 2900	- 7300	000	- 1000	+1000	-11200	-1900
x-13	- 6200	-10900	+ 8700	- 4700	+2100	-30500	+4600
x-14	- 6200	-10900	+ 8700	- 4700	+2100	-30500	+4600
x-16	- 4400	- 6500	+ 5300	- 2800	+1200	-19000	+2100
x-18	+ 2800	0	0	000	+3200	+ 6000	+2800
y- 1	- 2900	- 7300	- 7300	- 1000	0	-11200	-2900
y- 3	- 5800	-14600	-14600	- 2000	0	-22400	-5800
y- 5	- 8700	-21900	-21900	- 2900	0	-33500	-8700
y- 6	- 8700	-21900	-21900	- 2900	0	-33500	-8700
y-10	- 1600	- 5600	-17500	- 3800	+ 700	-22900	+11000
y-12	+ 5500	+10900	-13100	- 4600	+1500	+31000	-12200
y-15	+ 3600	+ 5500	- 4400	- 9300	+6100	+19600	-10100
y-17	- 2300	0	0	-11700	+6800	-14000	+ 4500
y-18	- 2300	0	0	000	- 3900	- 6200	- 2300
1- 2	- 3900	- 9700	- 9700	- 1300	0	-14900	- 3900
2- 3	+ 4900	12100	+12100	+1700	0	+18700	+ 4900
3- 4	- 5800	-14500	-14500	- 1900	0	-22200	- 5800
4- 5	+ 6500	16300	+16300	+ 2200	0	+25000	+ 6500
5- 6	-27100	-65600	-35100	+ 3100	- 2900	-95600	-24000
6- 7	+12000	+27200	+ 7400	- 1400	+1200	+40400	+10600
7- 8	+ 5900	+16500	+17500	- 6400	+ 2200	+25600	- 1500
8- 9	- 5200	-13100	0	- 1700	+1800	-20000	- 3400
9- 9	0	0	0	0	- 2900	- 2900	0
7-10	- 9500	-21800	- 5900	+1100	- 1000	-32300	- 8400
8-11	- 1200	0	+13100	- 5600	+1400	-19900	+13300
10-11	+12000	+27400	+ 7400	- 1400	+1200	+40600	+10600
11-12	- 9500	-21800	- 5900	+1100	- 1000	-32300	- 8400
12-13	+ 1100	0	+ 7400	- 3900	+3700	+12200	-10200
13-14	- 4400	- 7300	0	0	0	-11700	- 4400
14-15	+ 4300	+ 9200	- 7400	+ 3900	- 3700	+24800	- 6800
15-16	- 4000	- 3700	+ 3000	- 1500	+ 500	-12200	- 500
16-17	+ 7200	+ 6600	- 5300	+ 2800	- 900	+21900	+ 1000
17-18	-10900	- 7300	+ 5900	- 3100	- 4300	-28400	- 5000
R,	+27100	+65630	+35100	- 3100	+2900	+ 95600	+ 24000
V-R.	+10900	+ 7300	+ 5900	+ 3100	+4300	+ 28400	+ 5000
H-R	000	000	000	11700	10700		





## TABLE II

ADDITIONAL STRESSES IN TRANSVERSE TRUSS  
OVER COLUMNS.

	WIND LEFT	WIND RIGHT	MAX.	MIN.
x-13	+28300	-28300	+26100	-52000
x-14	+28300	-28300		
x- 7	+ 9430	- 9400	+26400	- 2300
x-16	+46000	-46000	+44100	-61000
x-11	+18870	-18900	+25200	-30800
y-10	- 9500	+ 9500	-32400	+20500
y-12	-19000	+19000	-31200	+50000
y-15	-38000	+38000	-48100	+57600
A-17	+63900	-63900	+49900	-59400
y- a	-90200	+90200	-90200	+90200
6- 7	-15800	+15800	- 5200	+56200
7-10	+12500	-12500	+ 4100	-44800
10-11	-15800	+15800	- 5200	+56400
11-12	+12500	-12500	+ 4100	-44800
12-13	-15800	+15800	-26000	+28000
14-15	+15800	-15800	+40600	-22600
15-16	-38000	+38000	-50200	+375000
16-17	-46000	+46000	-41300	+64200
17-18	+ 4500	- 4500		

WIND MOMENT IN REAR COLUMN.

$$H = 46800$$

$$d = 10 \times 12 \frac{1}{3} \times 69'' - 105'' = 38''$$

$$M = 46800 \times 38 = 1,780,000 \#''$$





connection of the seat-beam to the columns. Plate IV shows both in plan and elevation all bracing not indicated in the preceding plates.

For the design of the steel sections Ketchum's "General Specifications for Steel Mill Buildings" were used. The following are the unit stresses allowed by these specifications:

Tension - 16,000 pounds per square inch.

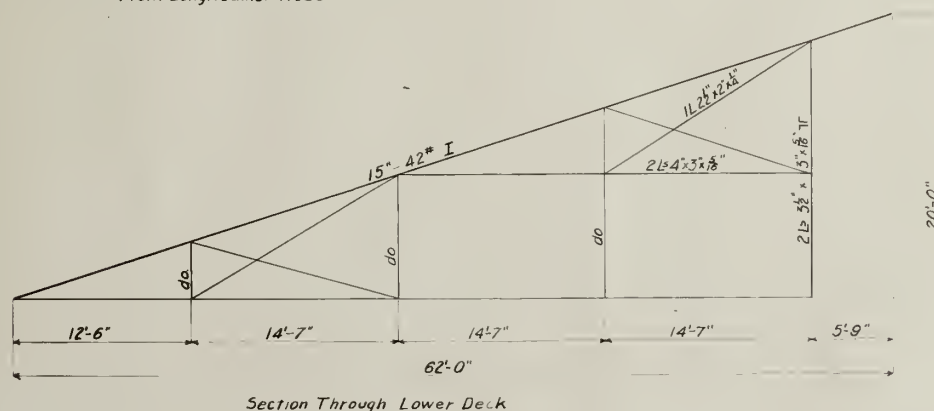
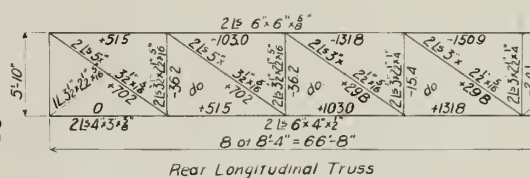
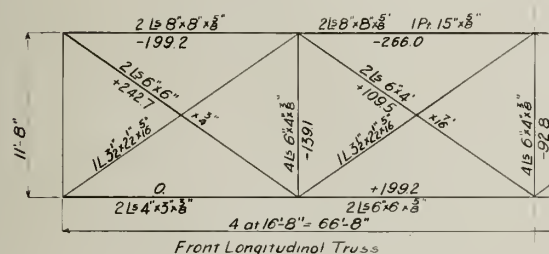
Compression -  $16,000 - 70 \frac{l}{r}$ , pounds per square inch,  
where  $l$  is the length in inches, and  $r$  is the least radius of gyration.

Shear on rivets - 11,000 pounds per square inch.

Bearing " " - 22,000 " " " "

Field rivets were considered as having two-thirds the value of shop rivets. The smallest angle used is a  $2 \frac{1}{2}$ "x 2"x  $\frac{1}{4}$ ".





Section Through Lower Deck

PLATE II  
DESIGN of a STEEL  
GRAND-STAND  
Diagrams Showing Main  
Members, Their Stresses,  
and the Sections Designed  
L. Mavel, Thesis Work, 1911.





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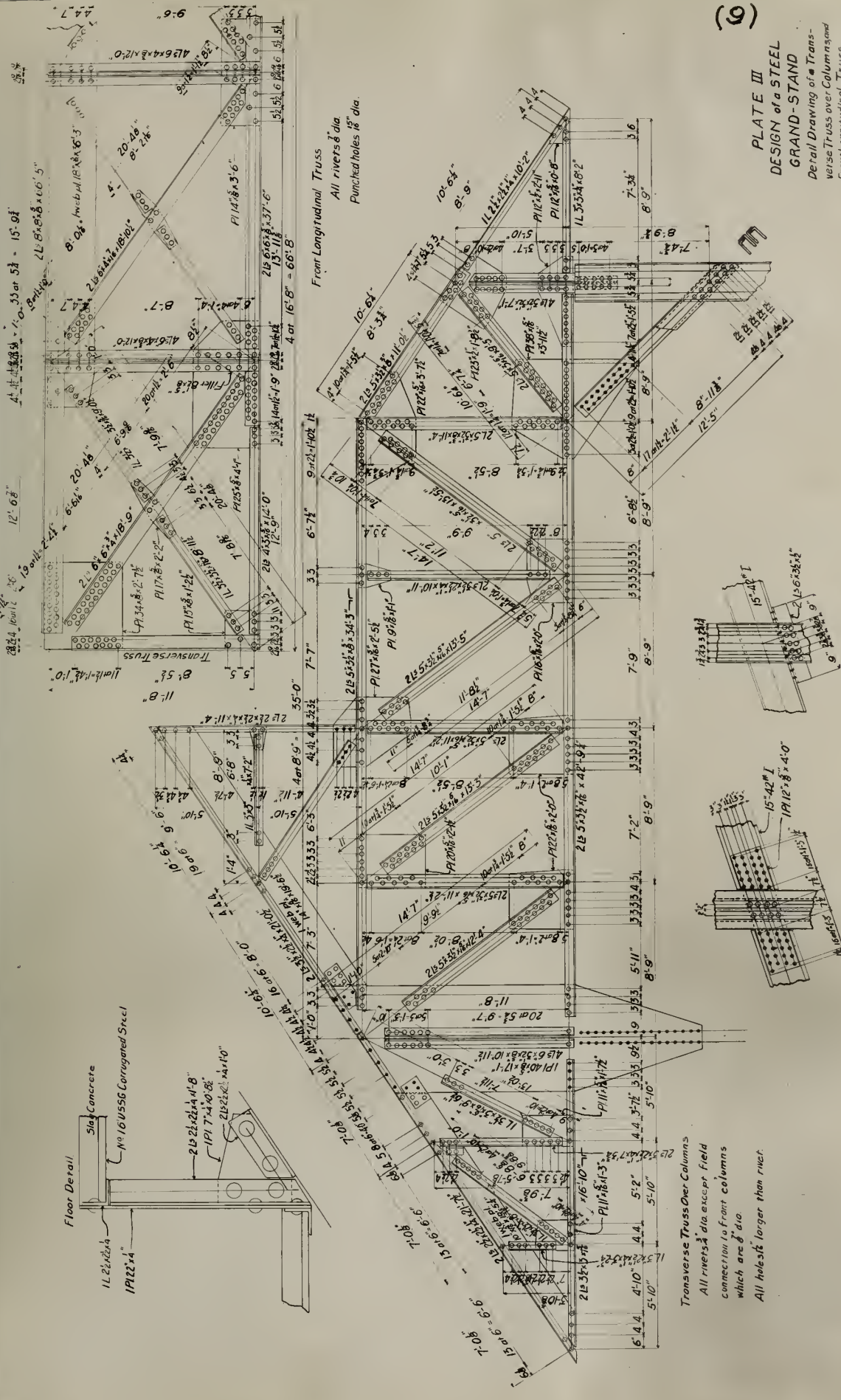
PLATE III  
DESIGN of a STEEL  
GRAND-STAND

Detail Drawing of a Trans-  
verse Truss over Columns and  
Front Longitudinal Truss.  
L. Maue.

Connection SearBeam  
to  
Rear Main Column.

Connection SearBeam  
to  
Front Main Column.

Transverse Truss Over Columns  
All rivets 3" dia except field  
connections in front columns  
which are 2" dia  
All holes larger than rivet.





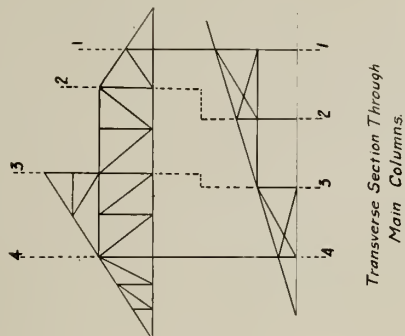
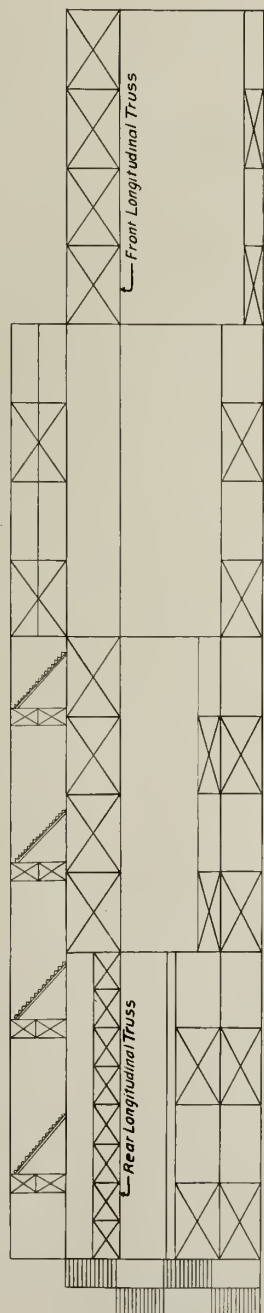


PLATE IV  
DESIGN of a STEEL  
GRAND-STAND

Diagrams Showing Wind  
Bracing and General Outline  
L. MaueI  
Thesis Work (1911)



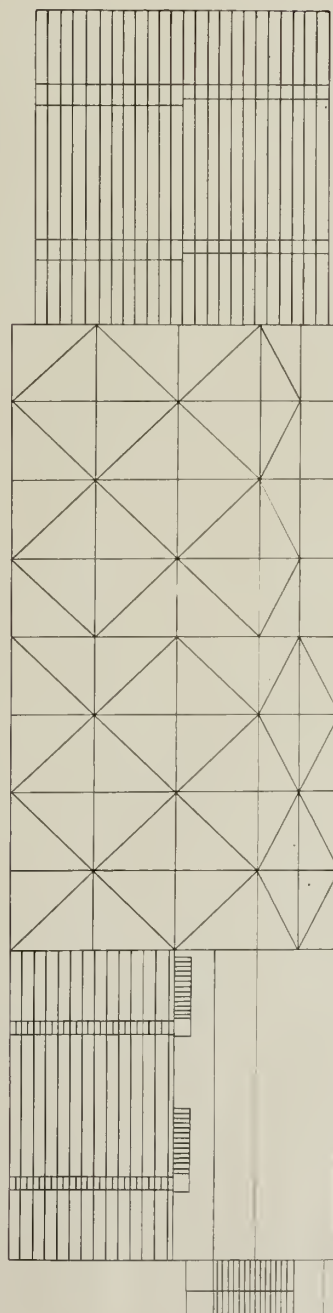
Section 4-4

Section 3-3

Section 2-2

Section 1-1

Longitudinal Sections



Plan Lower Deck

Bracing in Lower Chord

Bracing in Top Chord

Wind Bracing  
{ All diagonals - 1L 2 1/2 x 2 x 4  
All struts - 1L 4 x 4 x 3/8





ESTIMATE OF COST.

The cost of the grand-stand is as follows:

820,000 pounds of steel @ 3 1/2¢	\$28,700.00
329 yards floor concrete @ \$10.00	3,290.00
81 yards concrete footings @ \$5.00	405.00
122,000 pounds corrugated steel @ 3 1/2¢	4,270.00
2666' of 1 1/2" gas pipe @ 11¢	<u>300.00</u>
TOTAL ESTIMATED COST.	\$36,965.00











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